1-Octen-3-ol is repellent to *Ips pini* (Coleoptera: Curculionidae: Scolytinae) in the midwestern United States

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Abstract—In field experiments at three sites in Michigan and Ohio we tested the activity of 1-octen-3-ol in combination with ipsdienol, the aggregation pheromone of the pine engraver, *Ips pini* (Say). When 1-octen-3-ol was added to funnel traps baited with ipsdienol, significantly fewer beetles of either sex were captured than in traps baited with ipsdienol alone. This result suggests that the compound is potentially repellent and interrupts the response of beetles to their aggregation pheromone, and is consistent with previous reports of its inhibition of aggregation behaviour in other bark beetles.

Résumé—Dans des expériences sur le terrain dans trois sites du Michigan et de l'Ohio, nous avons testé l'activité du 1-octén-3-ol en combinaison avec l'ipsdiénol, la phéromone d'agrégation du scolyte du pin, *Ips pini* (Say). Quand on ajoute du 1-octén-3-ol aux pièges à entonnoir garnis d'ipsdiénol, les captures des coléoptères des deux sexes sont significativement moins importantes que dans les pièges munis d'ipsdiénol seul. Ces résultats indiquent que ce composé est potentiellement répulsif et perturbe la réaction des coléoptères à leur phéromone d'agrégation. Cette observation est en accord avec les inhibitions du comportement d'agrégation observées chez les autres scolytes.

[Traduit par la Rédaction]

1-Octen-3-ol, also known as mushroom alcohol, is an oxidation product of linoleic acid (Tressel *et al.* 1982; Assaf *et al.* 1995). It is a ubiquitous compound that occurs naturally in a wide range of sources, from volatiles emitted by fungi (Kaminski *et al.* 1972), flat bark beetles and bark beetles (Coleoptera: Cucujidae and Curculionidae: Scolytinae) (Klimetzek *et al.* 1989; Pierce *et al.* 1989), angiosperm trees (Zhang *et al.* 2000, 2001), and mammals (Hall *et al.* 1984; Raymer *et al.* 1985), to common foodstuffs such as fruit (Anderson and von Sydow 1964; Anjou and von Sydow 1967) and beans (Stevens *et al.* 1967; Buttery *et al.* 1975). Its function as a semiochemical for some species of insects (Pierce *et al.* 1988, 1989; Klimetzek *et al.* 1989) triggered further exploration of its use in managing bark beetles.

1-Octen-3-ol in bark beetles was first detected in the head-space volatiles of *Xylocleptes bispinus* (Duftschmid) in Europe, which it repelled in field tests (Klimetzek *et al.* 1989). In four North

Received 14 January 2009. Accepted 10 February 2009.

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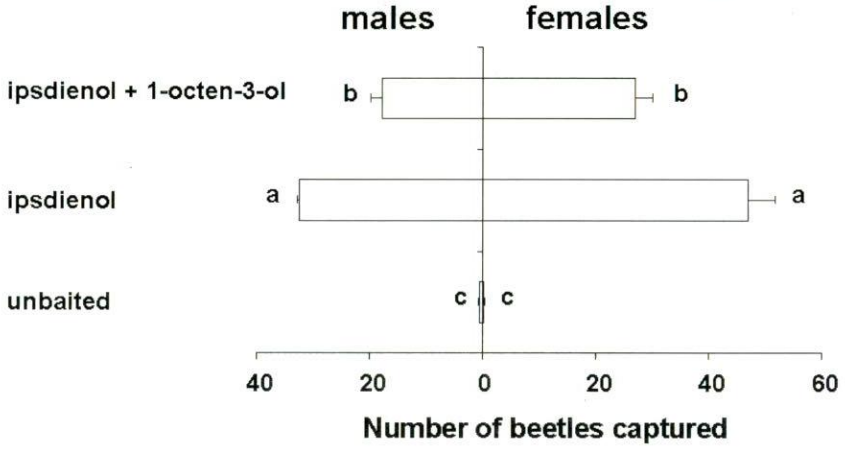
doi: 10.4039/n09-002

Fig. 1. Numbers (mean ± SE) of male and female *Ips pini* captured in multiple funnel traps baited with ipsdienol (0.11 mg/day) alone or combined with 1-octen-3-ol (2 mg/day) in Augusta, Michigan, and Toledo, Ohio, from 16 June to 26 August 2004 (n = 30). Within a sex, a different letter above the bar denotes a significant difference (Ryan–Einot–Gabriel–Welsch multiple-range test on data transformed by $\log_{10}(x + 1)$, $P < 0.05$).



American tree-killing bark beetles, the mountain pine beetle (*Dendroctonus ponderosae* Hopkins), Douglas-fir beetle (*D. pseudotsugae* Hopkins), spruce beetle, *D. rufipennis* (Kirby), and western balsam bark beetle (*Dryocoetes confusus* Swaine), (–)-1-octen-3-ol was identified in the volatiles of unmated females that were boring in log bolts and after they were joined by males (Pureswaran *et al.* 2004). Further electrophysiological studies revealed antennal responses of these four species to 1-octen-3-ol and it was hypothesized that the compound functions as an antiaggregation pheromone for some bark beetles (Pureswaran *et al.* 2004). In field experiments that pursued this hypothesis, (±)-1-octen-3-ol released at the rate of 5.5 mg/day reduced the response of both sexes of *D. pseudotsugae* and *D. ponderosae* to their aggregation pheromones and lowered the response of *D. rufipennis* to a level not significantly different from that in unbaited control traps (Pureswaran and Borden 2004). We expected a similar behavioural response from another bark beetle, the pine engraver, *Ips pini* (Say), in the midwestern United States of America.

We tested the activity of 1-octen-3-ol in mature red pine (*Pinus resinosa* Aiton) stands in the Maumee State Forest (41°32′N, 83°56′W) and Oak Openings Metro Park (41°34′N, 83°51′W) in Toledo, Ohio, and at the Kellogg Experimental Forest (42°22′N, 85°21′W) in Augusta, Michigan. There had been recent thinning activity at each site, and slash was available as breeding material for bark beetles and woodborers. Thirty 12-unit multiple funnel traps (Lindgren 1983) were set up at each of the three sites with one of three treatments: (1) unbaited control, (2) ipsdienol alone, and (3) ipsdienol + 1-octen-3-ol. Test compounds were obtained from Phero Tech Inc., Delta, British Columbia (now Contech Interprices, Inc.). Racemic (±)-ipsdienol was released from bubble caps at 0.11 mg/day and 1-octen-3-ol from bubble caps at 2 mg/day. The experiment was set up on 16–17 June 2004 in randomized complete blocks and run until 26 August 2004. Captured beetles were collected every 2 weeks, counted, and sexed (Lanier and Cameron 1969). Trap-catch counts were tested for normality using the univariate procedure and then transformed by $\log_{10}(x + 1)$ to meet the requirements of normality and homoscedasticity. Transformed data were subjected to analysis of variance followed by the Ryan–Einot–Gabriel–Welsch multiple-range test (Day and Quinn 1989). The effects were block, treatment, site, and site × treatment. All analyses were performed using SAS Institute Inc. (2002–2003) statistical software and $\alpha = 0.05$.

There was no block effect for either males ($F_{9,72} = 1.0$, $P = 0.45$) or females ($F_{9,72} = 1.03$, $P = 0.43$), but the effects of treatment (males: $F_{2,72} = 203.8$, $P < 0.0001$; females: $F_{2,72} = 227.5$, $P < 0.0001$) and site (males: $F_{2,72} = 7.52$, $P = 0.001$; females: $F_{2,72} = 3.44$, $P = 0.04$) were significant. The effect of site × treatment was significant for males ($F_{4,72} = 2.61$, $P = 0.04$) but not for females ($F_{4,72} = 1.67$, $P = 0.17$). When 1-octen-3-ol was added to ipsdienol,

46% fewer males and 42% fewer females were captured than in traps baited with ipsdienol alone (Fig. 1). However, the number of beetles captured in the ipsdienol + 1-octen-3-ol treatment was higher than in control traps (Fig. 1). The results suggest that 1-octen-3-ol potentially inhibits the response of *I. pini* to attractant-baited traps.

It is not known whether the compound is present in the volatiles of *I. pini* in the Midwest; it is not reported in the literature for this species from any other geographic location. Because the compound is ubiquitous, the response to it by *I. pini* could be due to the fact that it is a kairomonal indicator produced during previous infestation by a competing species of bark beetle (Pureswaran and Borden 2004), fungi associated with other bark beetles (Kaminski *et al.* 1972), or wood-rotting fungi. From any or all of these sources, this could render host trees less suitable for colonization.

We thank Erin Clark and Rachael Disipio for assistance in conducting experiments.

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